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UNITED STATES DEPARTMENT OF AGRICULTURE  
SOIL CONSERVATION SERVICE  
H. H. Bennett, Chief

Office of Research  
M. L. Nichols, Chief

APPLICATION OF HYDROLOGY TO SOIL AND WATER CONSERVATION

by

C. E. Ramser  
Chief, Hydrologic Division

This paper with slight changes  
presented at the Hydrology Con-  
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APPLICATION OF HYDROLOGY TO SOIL AND WATER CONSERVATION

by

C. E. Ramser <sup>1/</sup>

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The proper design of all soil and water conservation channels and structures used by the Soil Conservation Service depends upon the availability of hydrologic data. Available data for these uses are extremely meager. Without such data it is impossible to make accurate estimates of the run-off which must be handled by terraces, terrace outlet channels, diversion ditches, spillways, check dams, culverts, stock ponds, and other hydraulic works in water facilities and soil- and water- conservation operations. The lack of dependable information on run-off often results in the complete failure of such works. Even more frequently perhaps, insufficient information leads to the use of unnecessarily high factors of safety in the design of structures and thus to unjustifiably high costs.

The work of the Hydrologic Division of the Soil Conservation Service consists of the evaluation of land use and erosion-control practices in relation to their effect upon run-off, soil erosion, and flood flows; and of collecting information for the economic design of more effective erosion-control practices and flood control structures. This Division is divided into three sections: (1), Hydrologic Land Use, (2), Run-off Studies, primarily

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<sup>1/</sup> Principal Soil Conservationist, Chief of Hydrologic Division, Research, Soil Conservation Service.



for design of soil and water conservation practices, and (3), Soil and Water Conservation Hydraulics.

The Hydrologic Land Use Section has for its objectives the determination of the effect of land use practices upon run-off and erosion, upon disposal of precipitation, including its relation to groundwater, and upon flood flows. H. R. Leach was Head of this Section until his death on June 24, 1941. Mr. Waldo E. Smith was recently made head of this Section.

The Run-off Studies Section has for its objective the determination of run-off from agricultural areas and watersheds as a basis for the design of soil and water conservation measures primarily for use in the Operations work of the Soil Conservation Service. D. B. Kringold is head of this Section.

The Hydraulics Section has the following main objectives: (1) to increase the dependability and decrease the cost of hydraulic works used in soil and water conservation, and (2) to develop technical equipment for use in soil and water conservation research. D. A. Parsons is head of this Section which until December 1, 1940, was under the direction of H. L. Cook.

#### HYDROLOGIC LAND USE SECTION

Studies of the influences of land use on storm run-off, flood flow, silt production, and water conservation, which are being conducted by the Hydrologic Land Use Section, are planned to represent problem areas where soil and water conservation and flood control are closely related. These studies furnish information that is especially needed for carrying out the





provisions of the Omnibus Flood Control Act relating to the evaluation of land use and soil conservation measures in a national program of flood control.

The first main objective of the hydrologic land use studies is to furnish basic information necessary to a coordinated program of flood control for the safe-guarding of agricultural lands and industrial and urban developments against flood damages. The Nation is committed to enormous expenditures for flood control, and it is important that measures of flood control be complete and well coordinated and take into account all of the factors that affect floods. A knowledge of the influence of land use practices on run-off and erosion from complete natural watersheds is essential to the proper planning of watershed improvement programs directed toward the conservation of the soil, the reduction of floods, the better use of water resources, and the attainment of a balanced agricultural economy.

Thus far, three large projects have been initiated to collect information relating to this first objective, one within the Muskingum Conservancy District of Ohio, another within the Brazos Reclamation and Conservation District in Texas, and a third in the Central Great Plains in Nebraska. Smaller projects have been established on State-owned land in cooperation with the State Agricultural Experiment Stations at College Park, Md.; Lafayette, Ind.; Cherokee, Okla.; East Lansing, Michigan; and Ithaca, N. Y. Rainfall run-off studies are being carried on at the Navajo Experiment Station at Mexican Springs, N. M., to study







Fig. 1 - One of the fourteen flood control dams of the Muskingum Watershed Conservancy District.



Fig. 2 - Terraced orchard to conserve rainfall. Run-off from drainage area between terraces determines required height of terrace.

the characteristics of flood run-off from natural drainage areas of different sizes in the semiarid region of the Southwest.

The Muskingum studies are being conducted in cooperation with the Ohio State Agricultural Experiment Station and the Muskingum Conservancy District. The Conservancy District was formed for the purpose of providing protection against floods to the cities, towns, and farms lying in the valleys of the Muskingum River and its tributaries. With construction of flood control reservoirs by the War Department and the Muskingum Conservancy District well along toward completion, it was particularly appropriate that the first project undertaken by this Section should be representative of the North Appalachian hydrologic conditions and should lie in the heart of the Conservancy District. The District was quick to recognize the value of the studies on the influences of land use on flood flows and silting, and as a consequence, the resulting close cooperation with this association is mutually advantageous. The construction of fourteen flood control reservoirs by the U. S. Army Corps of Engineers for the Muskingum Conservancy District at a cost of about \$40,000,000 has been completed. (fig. 1 shows a view of one of the flood control reservoirs of the Muskingum Conservancy District.) Cooperative studies with the District have been initiated to extend the findings of the 5,000-acre experimental watershed near Coshocton, Ohio, to the 8,000 square miles of the Muskingum Conservancy District. Somewhat similar studies are being made on the Blacklands Experimental watershed, Llano, Texas, in cooperation with the Brazos River









Fig. 3 - View of water impounded above terraces on comparatively flat wheat land in western Kansas to conserve water for crops.



Fig. 4 - Contour furrowed field on which most of rainfall is conserved for crops.



Reclamation and Conservation District in Texas.

A knowledge of the influences of land use upon water conservation constitutes the second main objective of these studies and furnishes the basis for a forward-looking land use program particularly for the Great Plains drought area. Crop losses experienced by farmers, not only in the semihumid but the humid regions of the United States, during recent years indicate the need for improved agricultural practices to conserve all available moisture for crops. (See fig. 2 for a view showing terracing to conserve soil and moisture on orchard land in the Great Plains.)

It is quite common practice to build earth dykes at both ends of these level terraces so that all of the rain that falls on the land between the terraces is impounded in the channel above the lower terrace. (See fig. 3 for a view of water impounded above terraces on comparatively flat wheat land in western Kansas.) This practice increases infiltration and thereby makes available more water for crops resulting in increased crop yields. It is therefore important and essential to know how much water runs off of the land and accumulates above the terrace for the largest rain storms that occur in the region in order to plan the height and spacing of terraces properly and thus prevent breaks in terraces that result in severe damage to the land through the destructive effect of erosion. It is essential that the effectiveness of all erosion-control practices in conserving moisture, such as strip cropping, level terracing, and contour farming,







Fig. 5 ~ View of a basin listed field to conserve moisture and prevent movement of water along the furrows.

be ascertained in order to substantiate their adoption in a Nation-wide conservation program. In figure 4 is shown water collected in contour furrows after a heavy rain. These furrows must be laid out practically level and be of such depth and spacing as to hold the run-off for the largest storms that usually occur. Overtopping of the ridges where they have not sufficient height due to excessive run-off often results in damaging field erosion.

In the western wheat regions an improvement in the ordinary practice of contouring where the land is listed consists of introducing small earth dams in the furrows at close intervals of approximately 6 to 10 feet. This is known as basin listing, a view of which is shown in figure 5. Since it is extremely difficult to lay out contour furrows in ordinary farm operations without deviating from the level, the small dams prevent the water from running along the furrows and breaking over at low points. The dams are placed in the furrows in the regular listing operations by means of a lister equipped with a damming attachment.

A knowledge of the effect of land use and erosion-control practices upon surface and underground water supply for municipal, irrigation, and other purposes is important in a program designed to work out the proper relation between these uses and the consumption of water by plants grown on the watershed, which may in some cases be more or less conflicting. For instance, surface-water supplies for cities often command first consideration and demand that the watershed yielding the supply receive treatment



conducive to the maximum yield consistent with good land use. On the other hand, the replenishment of the underground supply by proper treatment of the watershed conducive to the maximum amount of infiltration may make available increased water supply from wells for municipal or irrigation purposes. The results of these experiments will indicate the possibilities of utilizing for the above purposes all of the rainfall water on a watershed, and thereby preventing the wastage of a large part of this water in surface run-off through the stream channels.

The effect upon the low water flow in streams resulting from proper treatment of the watersheds to increase infiltration and thereby the amount of water that reaches streams from underground sources deserves a detailed and comprehensive study. Immense financial benefits would result to both navigation and water power projects from better regulated and more uniform stream flow. For instance, the capital investment of a water power project is much less where uniform stream flow is available since this reduces the necessity for a large investment either for storage facilities or for an auxiliary steam power plant during periods of low flow.

Detailed investigations are being made on the large experimental watershed projects of the movement and action of water from the time it reaches the surface as precipitation until it leaves the watershed as surface or underground flow. These include studies of run-off and precipitation; percolation and infiltration; evaporation and transpiration; interception; surface, channel, and

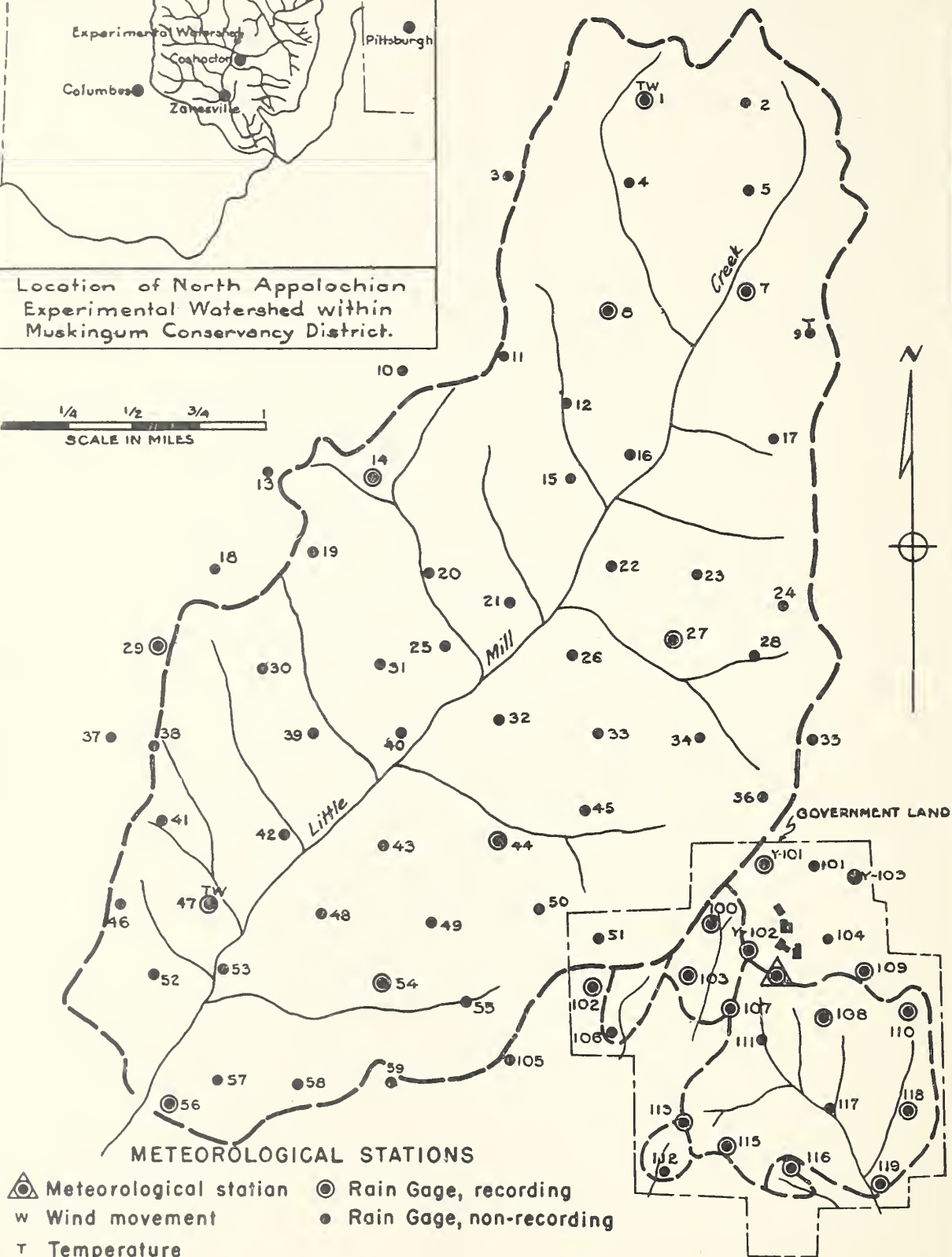


U.S. DEPARTMENT OF AGRICULTURE  
SOIL CONSERVATION SERVICE  
WATERSHED & HYDROLOGIC STUDIES  
COSHOCKTON, OHIO



Location of North Appalachian  
Experimental Watershed within  
Muskingum Conservancy District.

1/4 1/2 3/4 1  
SCALE IN MILES



N-2403

12-8-38  
4-3-39

Fig. 6







Fig. 7 - Third order meteorological station.



Fig. 8 - View showing second order meteorological station for the collection of data on precipitation and wind velocity.

underground storage; and movement of water under the ground surface and through stream channels. Studies of precipitation relate to amount, intensity, duration, and aerial distribution. Careful analysis is made of physical characteristics of the watershed relating to soil and subsoil, topography, physiography, vegetal cover, geologic formations, and cultural factors such as tillage and erosion-control practices. The general plan of study includes, (1) the evaluation of all important factors by comprehensive and detailed experimental studies, and (2) tracing the effect of these factors from small to large watersheds.

Meteorological data are being collected at a sufficient number of places over the large experimental watersheds of about 5,000 acres each to furnish complete and reliable information on meteorological conditions over the watershed during the period of investigation. Locations of meteorological stations of the first, second, and third order for the North Appalachian Experimental watershed near Coshocton, Ohio, are shown on the map in figure 6. One first order meteorological station, 27 second order stations and 55 third order stations have been established. Third order stations (see fig. 7) are equipped only with a standard 8" non-recording rain gage and a snow board, surrounded by a fence for protection. The second order stations (see fig. 8) are provided with a standard 8" rain gage, a self-recording rain gage, and a snow board. Some of these stations are also equipped with a maximum and minimum thermometer and an anemometer.





Fig. 9 - First order meteorological station.



Fig. 10 - View of a strip cropped field on the Coshocton Experimental Watershed Project.





Fig. 11 - View of a pasture watershed on the Coshocton,  
Ohio Project.



Fig. 12 - View of a terrace which has a graded channel to  
carry the water away slowly to the end of the  
terrace.

A first order meteorological station (see fig. 9) is equipped with a standard 8" rain gage, a self-recording rain gage, an evaporation pan, an anemograph, a sunshine duration transmitter, an anemometer, a barograph, a hygrothermograph, a standard mercurial barometer, a sling psychrometer, a hail gage, a soil thermograph, a set of maximum and minimum thermometers, and a snow board.

Small watersheds of one to ten acres are used for experiments to determine the effect of erosion-control practices on the rates and amounts of run-off and soil erosion for rainfall of different amounts and intensities. Erosion-control practices to be used will depend on their adaptability to the particular region. Some of these practices will be pasture, forest, cover crops, green manure crops, crop rotations, various tillage methods, contouring, strip cropping, and terracing. (See fig. 10 for a view of a strip-cropped field.) In figure 11 is shown a view of a pasture watershed. The effect of the erosion-resisting strip, used in strip cropping, upon the rate and amount of run-off from a field has never been carefully evaluated for practical application to large field problems. In figure 12 is shown a view of a terrace which has a graded channel to carry the water away slowly to the end of the terrace. It is readily apparent that a knowledge of the run-off from the land between the terrace is essential to the determination of the proper grade and cross section required for the terrace channel.



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WATERSHED & HYDROLOGIC STUDIES  
COSHOCKTON, OHIO



Location of North Appalachian  
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Muskingum Conservancy District.

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SCALE IN MILES

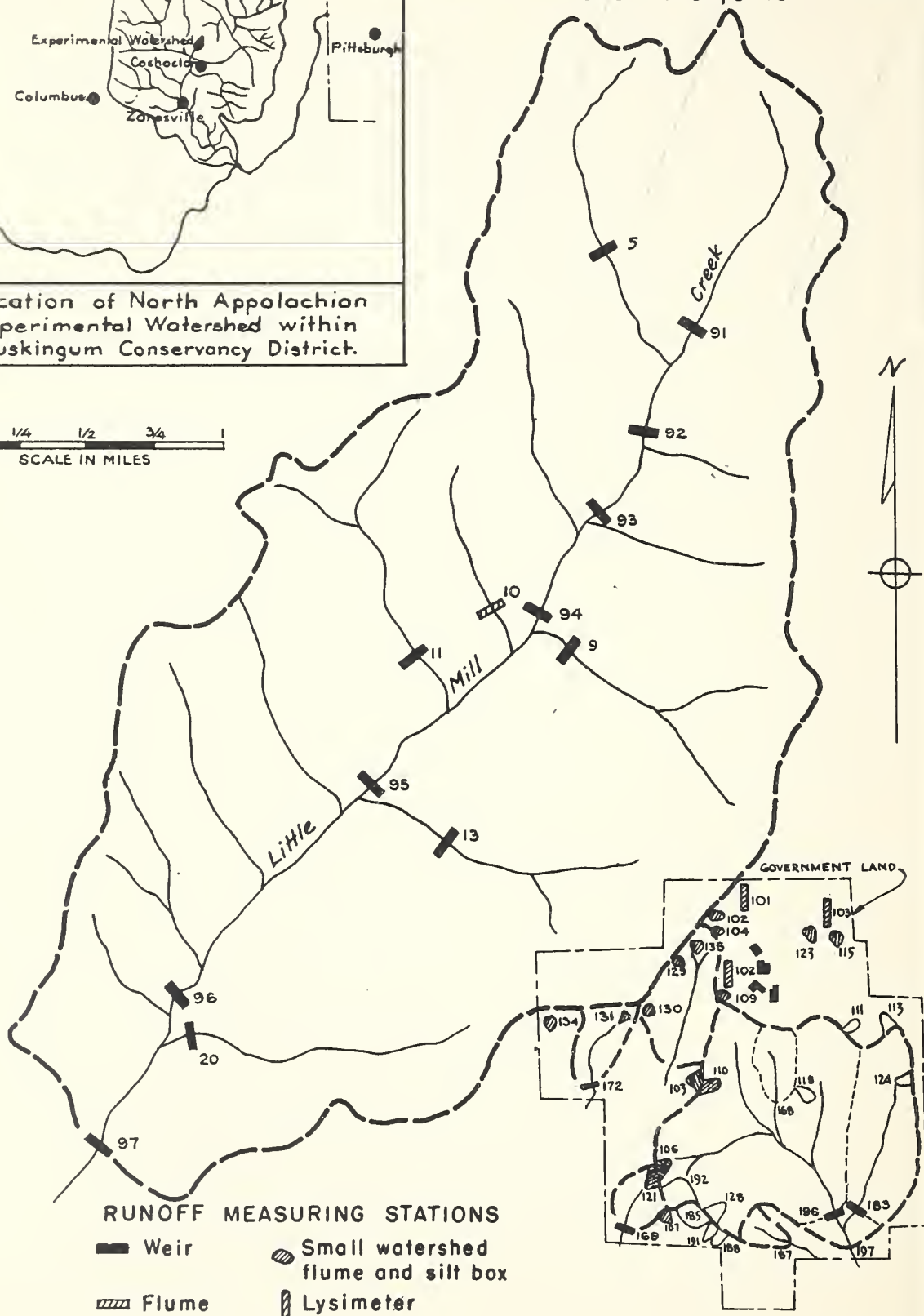


Fig. 13

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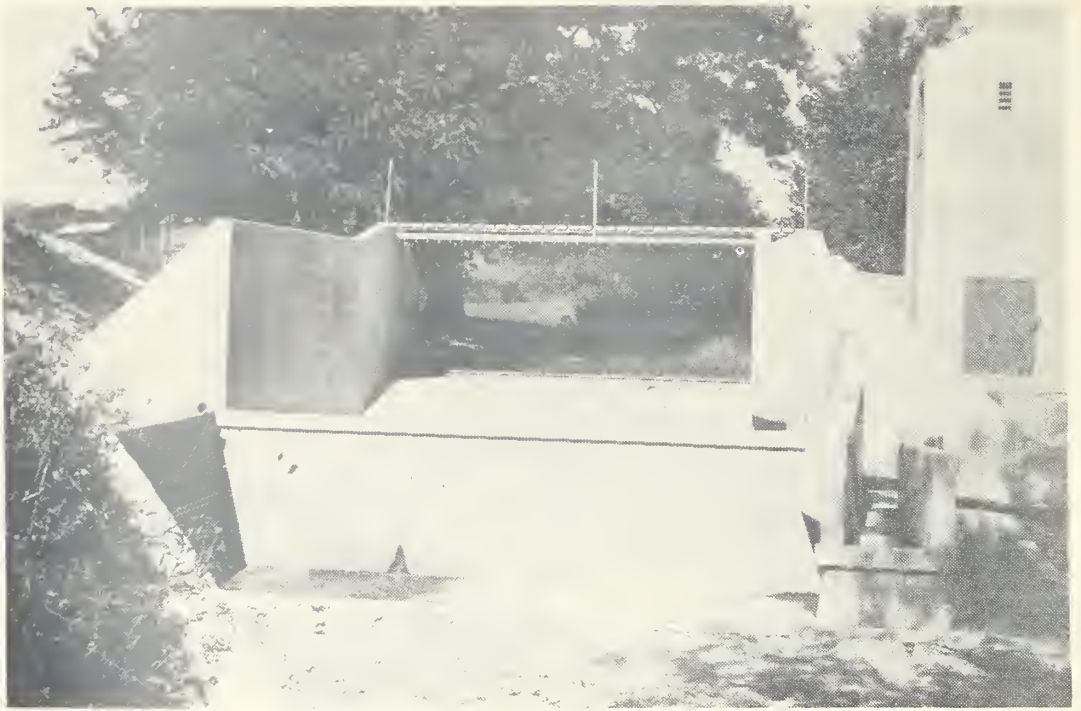


Fig. 14 - Downstream view of the dual Parshall flume which includes a small side flume for measuring low water flow.



Fig. 15 - View of a current meter gaging station with low water control at Coshocton, Ohio.

Two rather similar watersheds of about 400 acres each have been selected on the Coshocton and Laco Projects for the purpose of conducting run-off and other investigations under present land use practices. This will represent the first stage of experimental studies. Afterward, improved land use and erosion-control methods will be put into practice on one of the watersheds and the other of the two similar watersheds will be continued under the same practices used during the first stage - this to obtain comparative data on the effect of an improved land use and erosion-control program upon water conservation, run-off, and flood control for comparatively large areas.

In watersheds ranging in size from 30 to 5,000 acres, information on the rates and amounts of run-off and erosion from rains of different amounts, durations, and intensities will be collected to determine the effect of the size of the watershed on the rate and amount of run-off. (See fig. 13 for location of run-off measuring stations on the Coshocton Project.)

Similar mixed land use practices and erosion-control measures will be maintained on these watersheds so as to eliminate as far as possible any difference in run-off due to these practices.

At the outlets of all watersheds, gauging stations have been constructed. In the intermediate watersheds, the Parshall flume and dual Parshall flumes have been installed (see fig. ~~13~~<sup>14</sup>, a downstream view of the dual Parshall flume, which includes a small side flume for measuring low water flow.) On the larger watersheds foot bridges and cable stations have been constructed





Fig. 16 - View of a new bridge gaging station and broad-crested triangular weir for low water control at Hastings, Nebr.



Fig. 17 - View showing Parshall concrete measuring flume and Ramser silt sampler used in the measurement of run-off and soil losses from small watersheds.





Fig. 18 - Parshall measuring flume and Ramser silt sampler in operation during period of run-off.



Fig. 19 - Terrace outlet channel seeded to grass to prevent erosion; width and depth of channel is governed by size and nature of drainage area which contributes run-off water.



for making current meter measurements. (See fig. 15 showing a view of a current meter gaging station with low water control at Coshocton, Ohio, and fig. 16 for a view of a new bridge current meter gaging station and broad-crested triangular weir for low water control at Hastings, Nebraska.) The Parshall flume or Type-1 flume combined with a Ramser silt sampler is employed for the measurement of run-off and soil losses from small watersheds. (See fig. 17 for a view of a concrete Parshall flume and Ramser silt sampler, and fig. 18 for a view of a Parshall measuring flume and Ramser silt sampler in operation during period of run-off.)

Studies will be made of the accumulations of flood flows from small areas and of assembly and propagation of flood flows through the larger stream channels to determine the flow and stage reached as the flood progresses downstream. This is a matter on which factual data are extremely inadequate. The rational solution of the land use phase of flood problems depends on a thorough knowledge of hydrology and the hydraulics of flood phenomena from rivulets to larger streams. Not until the accumulative effects of land use on small areas can be traced to major flood flows will it be possible to determine quantitatively the influence of various types of land use on flood flows.

The possibility of a much wider geographical extension of the results obtained will be investigated through run-off measurements on small plots, using artificial applications of





rainfall. This will make possible the immediate collection of data by eliminating the necessity of awaiting the occurrence of the entire range of rainfall conditions during natural storms. It is anticipated that the relation between run-off from small plots and that from watershed areas can be established reliably, thus enabling an extrapolation of the watershed results throughout the region represented by the study. Some of the accomplishments to date follow:

Records were collected on the Blacklands Experimental Watershed, Waco, Texas, during November and December, 1940, for storms of unusual severity, which will be valuable for use in the design of soil and water conservation measures in connection with soil conservation districts. Hydrologic data from this project were supplied to the Project Plans Division of the Soil Conservation Service for use in the preparation of the flood control report on the Trinity River in Texas.

Basic hydrologic data from the Central Great Plains Experimental Watershed at Hastings, Nebraska, were prepared for publication in bulletin form, which will be particularly applicable for use on Operations and Water Facilities projects of the Soil Conservation Service in this region. The work at this station was expanded to include a study of the effects of crop residues upon moisture conservation on a watershed basis where regular tillage methods are employed in order to check results obtained from plot studies at Lincoln, Nebraska. Run-off measuring equipment was installed on six additional watersheds for these studies.



Analysis was made of hydrologic data collected on the North Appalachian Experimental Watershed, Coshocton, Ohio, in cooperation with the War Department engineers, for use in the preparation of reports of joint flood control projects of the Department of Agriculture and the War Department. Basic hydrologic data were prepared for publication for use in connection with the design of soil conservation works on field projects.

Installation of measuring equipment was completed on the newly established project at East Lansing, Michigan, in cooperation with the State Agricultural Experiment Station, to study the manner in which freezing and thawing of soils on watersheds with different types of land use and snow cover contribute to run-off, erosion, and flood flow under northern winter conditions.

The network of recording rain gauges at the Navajo Experiment Station at Mexican Springs, N. M., was utilized to make a much needed study of the areal extent of severe storms in the arid southwest. Rainfall data were furnished the War Department for studies required in connection with the preparation of flood control reports in the southwest, in cooperation with the Department of Agriculture.

The outstanding accomplishment of this past year consists in making the data available in published form for use in the planning of conservation practices for soil conservation districts, Water Facilities projects and flood control projects. The phase of the work in which the most fruitful eventual results



Fig. 20 - View of terrace outlet channel protected from erosion by grass and low concrete check dams.



Fig. 21 - View of a method of preventing erosion in roadside ditches in Illinois by means of concrete dams. Size of notch must be adequate to handle run-off water from drainage area.







Fig. 22 - Showing notch in a log check dam; cross section area of notch must be sufficient to handle runoff water from the drainage area above.

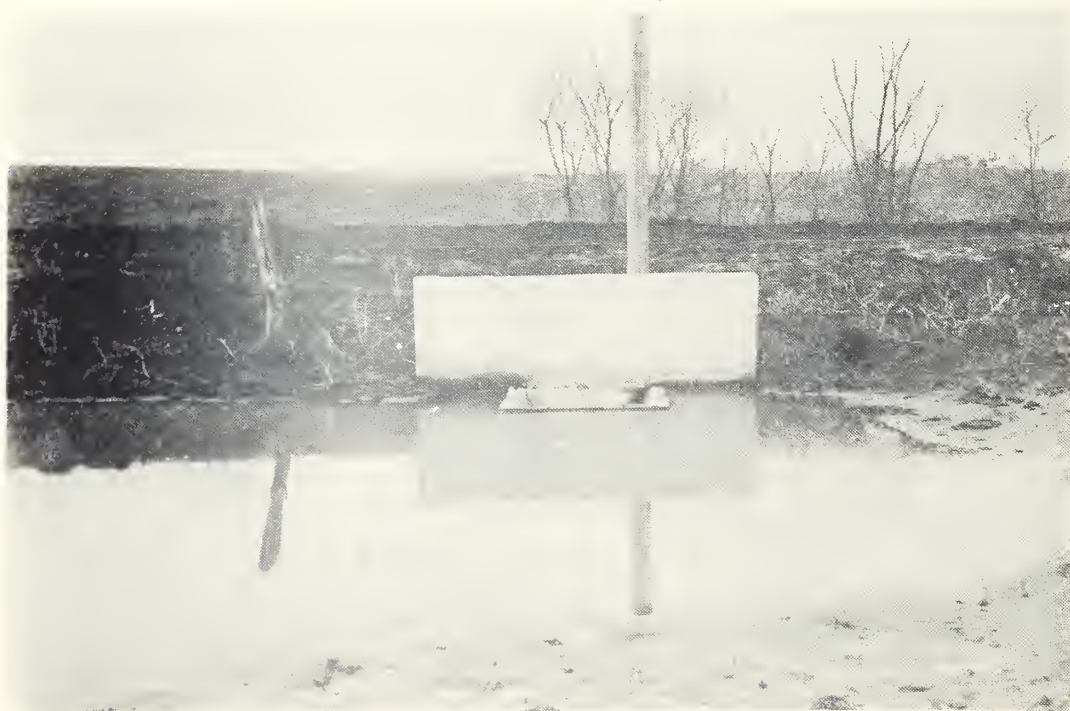


Fig. 23 - View of soil saving dam with vertical drop inlet culvert showing soil deposited level with entrance to drop inlet culvert. Cross section of culvert must be large enough to provide for removal of runoff water from the drainage area.



seen likely to be obtained is the determination of the quantitative effects of combined soil-conservation practices upon the control of floods.

#### RUN-OFF STUDIES SECTION

As has been stated, the primary objective of the Run-off Studies Section, the second of the three sections of the Hydrologic Division, is to furnish much needed information on rates and amounts of run-off, especially to the Operations projects of the Soil Conservation Service, for the economic design of erosion-control structures and for related purposes. (See fig. 19 for a view of a terrace outlet channel seeded in grass and fig. 20 for a view of a terrace outlet channel protected from erosion by grass and low concrete check dams.) In figure 21 is shown a method of preventing erosion in roadside ditches in Illinois by means of concrete check dams. In figure 22 is a view of a log check dam commonly constructed where timber is conveniently at hand. In figure 23 is a view of a soil saving dam with vertical drop inlet culvert showing soil deposited level with entrance to drop inlet culvert. In figure 24 is a corrugated metal flume built to convey water into the head of a gully with a minimum amount of erosion.

It can be readily seen that the satisfactory design of notches for check dams, drop inlet culverts for soil saving dams, outlet ditches for terraces, and channels for flumes and diversion ditches for a variety of purposes - all of which are used in soil conservation work - depends upon reliable run-off



Fig. 24 - View of a corrugated metal flume built to convey water into the head of a gully with a minimum amount of erosion. Flume must be designed to take care of water running off the drainage area.



Fig. 25 - View of dam and pond with spillway built under the Water Facilities Act to provide water supply for farm uses. Spillway must be large enough to pass excess run-off water during heavy storms and thus prevent overtopping of the dam.

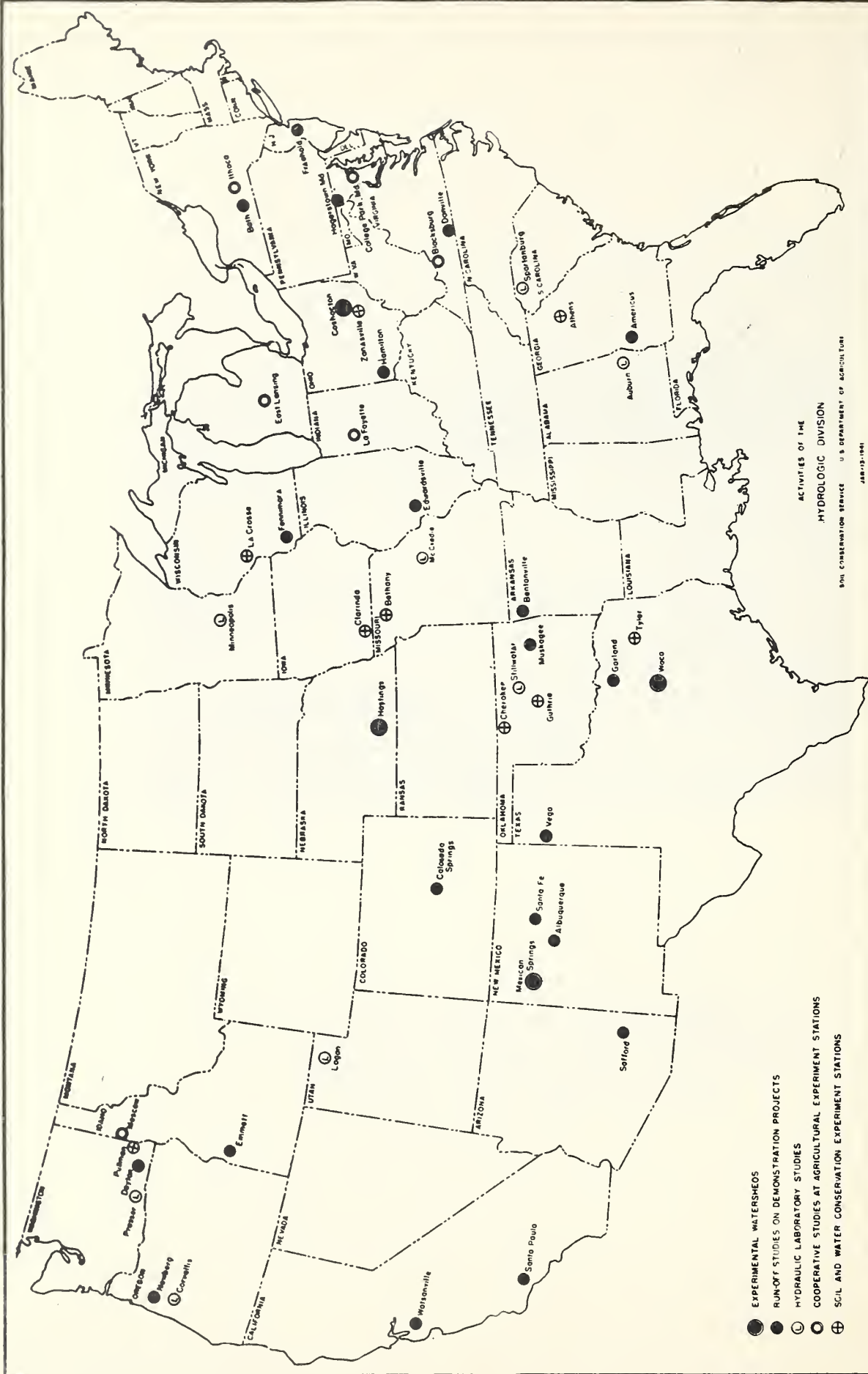




Fig. 26 - View of a reservoir and spillway constructed on one of the land utilization projects for recreational purposes. Size of spillway is carefully planned to provide for high rates of run-off from the drainage area above.









information from land areas. Structures may be under-designed, resulting in failures, or over-designed, resulting in wasteful expenditures. Adequate run-off data should be made available as a basis of design. The numerous failures due to inadequate waterways for farm ponds, road bridges, culverts, and similar hydraulic structures are evidence of the lack of data on run-off. The data being collected are also particularly needed at the present time in carrying out the provisions of the Water Facilities Act of the U. S. Department of Agriculture. (See fig. 25 for a view of dam and pond with grass spillway on an Operations project of the Soil Conservation Service to provide water supply for farm uses.) (See fig. 26 for a view of a reservoir and spillway constructed on one of the land utilization projects for recreational purposes.)

Intensive studies designed to collect the foregoing information are being conducted on the watershed projects located throughout the country. (Fig. 27 shows the location of these projects on an United States map.) In addition to the large experimental watersheds in Ohio, Texas, and Nebraska, shown on the map, run-off studies are being conducted on 98 small watersheds located on 23 different Operations projects of the Soil Conservation Service in different parts of the country. From three to six typical drainage areas were selected on each one of these projects. Preliminary topographic, soil, and cover maps of the selected areas as well as plans, profiles, and cross sections of the proposed sites for the run-off measuring stations together with a complete description of the areas and of the



Fig. 28 - Downstream view of broad-crested triangular weir showing concrete apron below.



Fig. 29 - View of a 3:1 broad-crested triangular weir with stilling well located 10' upstream from the center of weir crest.

cropping plans were prepared.

In order to attain the objective of the run-off studies, the information secured must include (1) adequate run-off hydrographs, (2) complete records of amounts, rates, distribution, and time of occurrence of precipitation, (3) accurate information on the permanent characteristics of the drainage areas, and (4) sufficient data on the conditions of the soil and vegetal cover at the time run-off occurs.

The storm run-off from small drainage basins is of very short duration. The fluctuations in stage are very rapid and the critical peak flows continue for only a few minutes. It is extremely difficult and often impossible to secure adequate run-off hydrographs from such drainage basins by means of current meter measurements. It was, therefore, necessary to develop some sort of an automatic run-off measuring device for obtaining the discharge measurements. After engineers of the Hydrologic Division had considered all available measuring devices, including weirs and flumes, it was found that a triangular broad-crested weir would be most suitable to meet the requirements. Preliminary investigations were conducted at the National Hydraulic Laboratory, Washington, D. C., on small scale models in order to develop the simplest possible weir crest suitable for the purpose. These investigations resulted in the broad-crested triangular weir shown in figure 28. Triangular weirs with this crest and side slopes of 2 horizontal to 1 vertical, 3 to 1 and 5 to 1 are employed. In figure 29 is shown





Fig 30 - Surface of pondage for a fairly high stage at a broad-crested triangular weir with 2:1 side slopes near Freehold, New Jersey

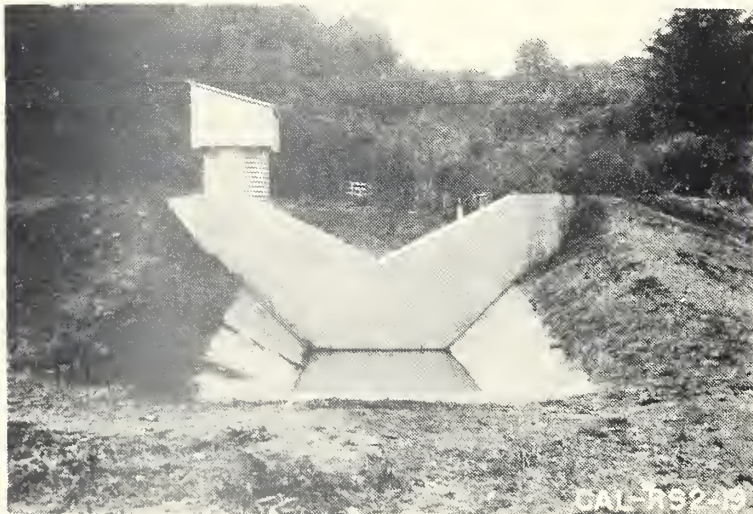


Fig. 31 - Downstream view of a broad-crested triangular weir located on a wooded watershed of 10.1 acres near Watsonville, Calif.







Fig. 32 - View of a very steep watershed covered with cheat grass and sage brush, having an area of 69.4 acres near Emmett, Idaho



Fig. 33 - View of a watershed of 330 acres with a fairly moderate slope near Fennimore, Wisc.







Fig. 34 - A typical rangeland watershed of 140 acres  
sparsely covered with juniper trees near  
Santa Fe., N. M.

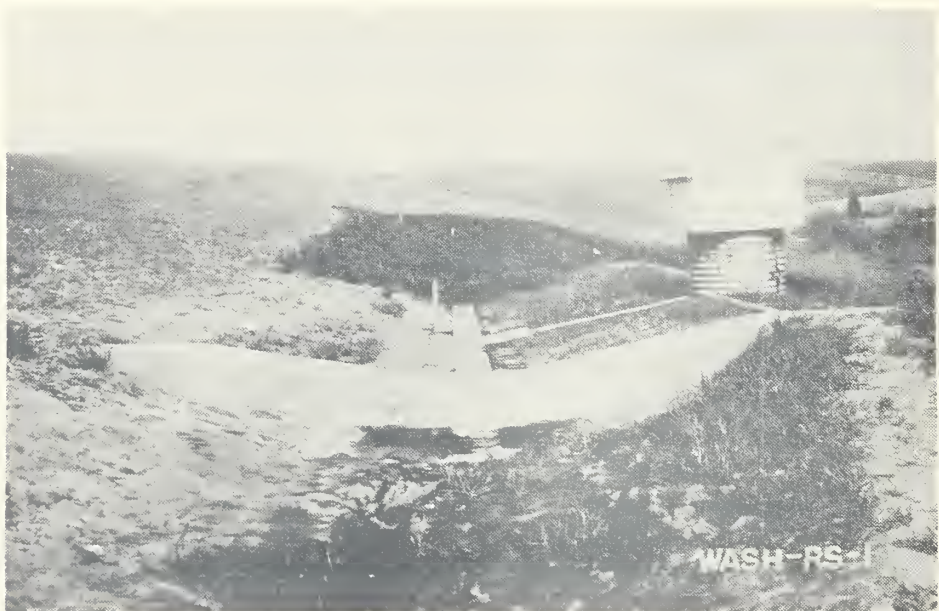


Fig. 35 - View of a hillside watershed located in the  
Palouse wheatland area near Dayton, Wash.

a view of a 3:1 broad-crested triangular weir with stilling well located 10' upstream from center of weir crest. In figure 30 is shown an upstream view of a measuring weir during a flood stage. From this view an idea can be obtained as to the pondage effect above the weir at a fairly high stage.

A great variety of cover conditions exist on the 98 small watersheds located throughout the United States, where run-off measurements are being made and in the following figures are shown views of the cover conditions of a number of these typical watersheds: In figure 31 is shown a downstream view of a broad-crested weir located on a wooded watershed of 10.1 acres near Watsonville, Calif. Figure 32 shows a very steep watershed covered with cheat grass and sage brush having an area of 69.4 acres, near Emmett, Idaho. In figure 33 is shown a watershed of 330 acres with fairly moderate slope, near Fennimore, Wisc. This area is representative of the general farming area in that part of Wisconsin on which a variety of crops are grown. Figure 34 shows a typical range land watershed of 140 acres, sparsely covered with juniper trees, near Santa Fe, N. M. In figure 35 is shown a hillside watershed located in the Palouse wheatland area near Dayton, Wash. This watershed has an area of 19.2 acres which is drained by a hillside diversion ditch, at the lower end of which is located the broad-crested weir shown in the picture.

Some of the accomplishments during the past year of the Run-off Studies Section follow:

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For information regarding the publication of notices of deaths, see page 1000 of this issue.



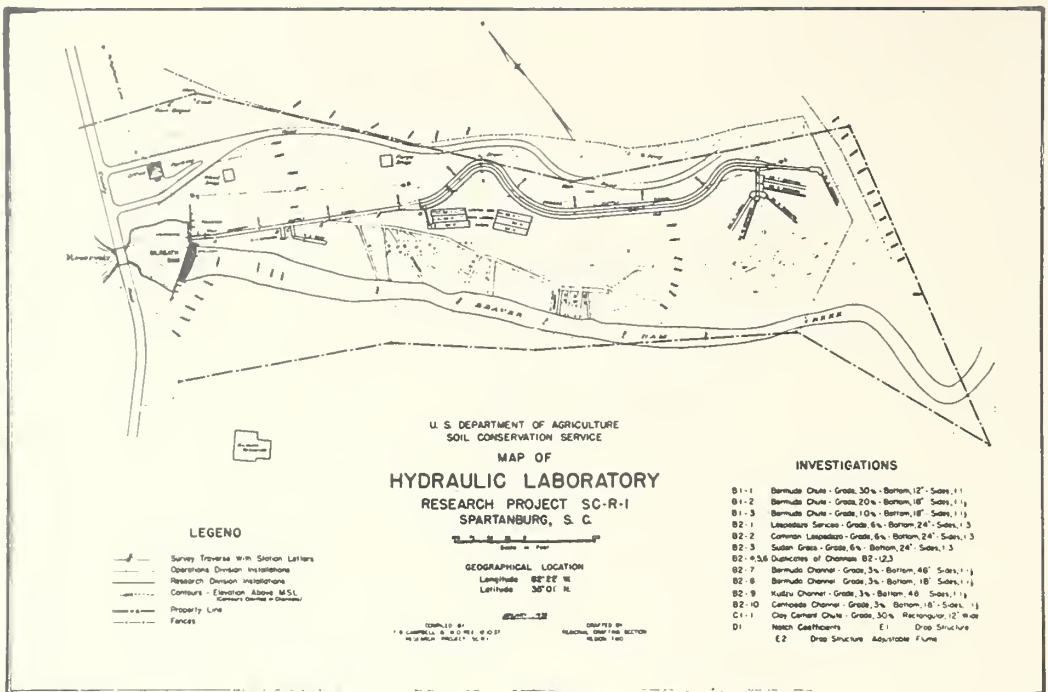
The collection of data was continued on all watersheds established prior to July 1, 1940. Work plans were prepared and the instrumentation is completed or in progress of completion on watersheds established after July 1, 1940. Progress is being made in overcoming difficulties encountered in measuring run-off from highly erodible areas which produce unusually large quantities of silt. A large number of records has been compiled and subjected to preliminary analysis.

Conferences on the application of the results were held in the several regions with Operations technicians, the ultimate users of the data. It was found that definite recommendations cannot be made before several years of data are collected, compiled and analyzed. However, in view of the great need for even fragmentary data, reports containing tentative results (subject to revision in the light of future observations) are being prepared for each of the Soil Conservation Service regions.

Progress was made on the preparation of bulletins describing the characteristics of the watersheds and of the procedure employed in collecting, compiling, and analyzing the data. The results of the investigations were utilized in the preparation of flood control survey reports for the Trinity, Potomac, Susquehanna, Gila and other rivers.

#### HYDRAULICS SECTION

The work of the Hydraulics Section evolved from a cooperative undertaking started in 1934 by the Soil Erosion Service and the



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Fig. 36 - General layout of the Spartanburg Outdoor Hydraulic Laboratory

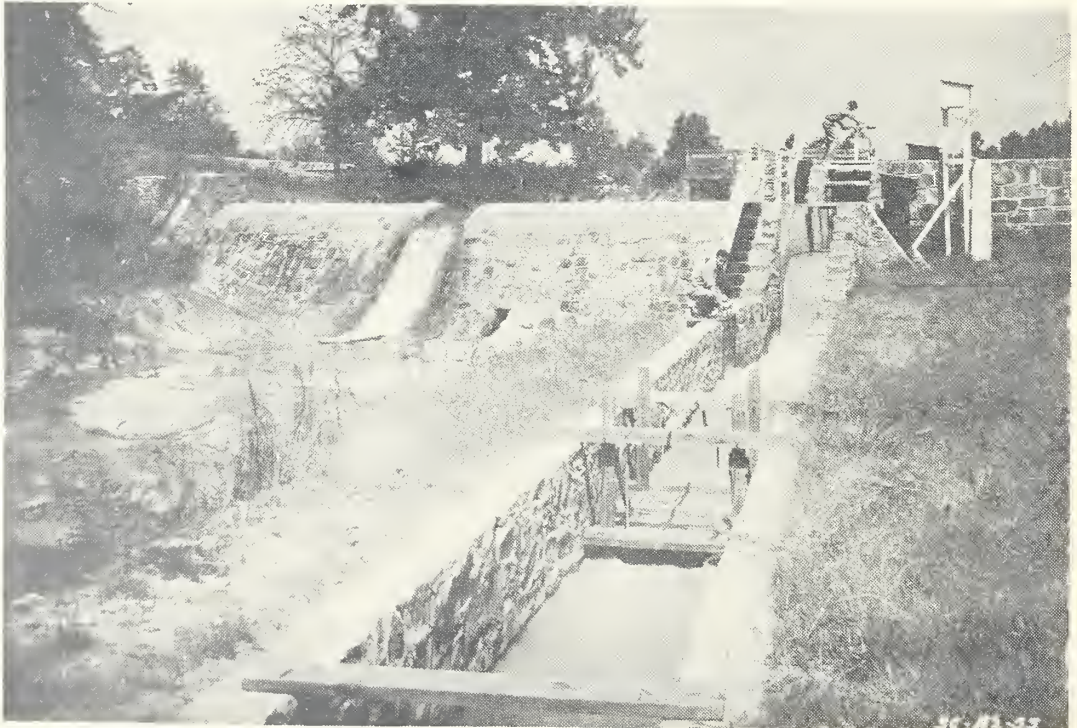


Fig. 37 - View of dam, headworks, and measuring weir at the Spartanburg Outdoor Hydraulic Laboratory, S. C.

National Bureau of Standards, for the purpose of testing and developing measuring equipment for use in soil conservation research. With the growth of the demonstration work of the Soil Conservation Service it became evident that in the conservation of soil and water, the most difficult problems and the most costly operations are those associated with the removal and disposal of the run-off from agricultural lands. In 1936, a program of hydraulic research dealing with these problems was outlined in collaboration with engineers of the Office of Operations of the Soil Conservation Service. The first step in this expanded program was taken in 1936 by the establishment of an outdoor hydraulic laboratory near Spartanburg, S. C. (See fig. 36 for general layout of the Spartanburg Outdoor Hydraulic Laboratory.) At the present time plans are being made for the establishment of a second outdoor hydraulic laboratory near Stillwater, Okla. Cooperative work has also been started at the University of Minnesota in the large new hydraulic laboratory recently completed in Minneapolis, and in both indoor and outdoor laboratories at the Polytechnic Institute at Auburn, Ala. Other outdoor experiments relating to soil conservation measures are being carried on at a number of the experiment stations of the Soil Conservation Service. All of this work is carried on in cooperation with the state agricultural experiment stations.





Fig. 38 - View of lespedeza meadow-strip channel during test to determine roughness coefficient.



Fig. 39 - View of meadow-strip terrace outlet channel. Nature of growth in this channel determines its capacity to remove run-off water.

In order to carry out the necessary investigations with maximum dispatch and at minimum cost, the method of study varies with the nature of the individual problem. Certain fundamental studies are being carried out in cooperation with established hydraulic laboratories (see fig. 37 for a view of dam, headworks, and measuring weir at the Spartanburg, S. C. Laboratory); problems varying with location but requiring experimentation under controlled conditions are being studied at temporary outdoor hydraulic laboratories; established hydraulic works on the demonstration and research projects of the Soil Conservation Service are being studied under actual field conditions; and other lines of attack will be developed for special problems that cannot be expeditiously or economically solved in the ways outlined above.

The lines of research under way or proposed are:

(1) Studies of the hydraulic characteristics of the channels and other structures used in the conveyance and disposal of the run-off from farm lands.

These studies will determine the hydraulic characteristics of terrace outlet and other channels, check dams, drop inlets, spillways, water spreading, and other conservation structures. They will be carried out at indoor and outdoor hydraulic laboratories. Special attention will be given to the determination of the roughness coefficient of channels, with various vegetal linings, for use in the design of such channels in soil and water conservation programs. (See fig. 38 for a view of





Fig. 40 - View of channel in Sudan grass under hydraulic test to determine the probable safe velocity for channels with Sudan grass lining.





Fig. 41 - View of channel in Bermuda grass under hydraulic test to determine the probable safe velocity for channels with Bermuda grass lining.

lespedeza meadow-strip channel during test to determine roughness coefficient.) (See fig. 39 for a meadow-strip terrace outlet channel.) These broad, shallow channels are usually planted to perennial grasses and valuable hay crops are produced in the channels.

(2) The second of the hydraulic studies consists of methods for preventing the failure of the channels and other hydraulic structures used in soil and water conservation operations.

These studies deal with the prevention of scour and silting in channels, especially those lined with vegetation; with the improvement of methods of dissipating energy below overfalls, at the bottom of steep channels, and at other points where excess energy may cause damage; and with other factors affecting the safety and life of the hydraulic works used in conservation activities. Basic experiments will be made at indoor and outdoor laboratories and field tests will be carried out on demonstration projects. (See fig. 40 for a view of channel in Sudan grass under hydraulic test to determine the probable safe velocity for channels lined with this grass; fig. 41 for a similar test for Bermuda grass; and fig. 42 for a similar test for Kudzu.)

(3) The third of the hydraulic studies consists of the development of economical terrace outlet and other hydraulic systems used for conveying and disposing of run-off.





Fig. 42 - View of channel in kudzu grass under hydraulic test to determine the probable safe velocity for channels with kudzu grass lining.



Fig. 43 - View of Type-H flume developed in the Bureau of Standards Hydraulic Laboratory by engineers of the Hydrologic Division for measurement of flow of water with minimum amount of silting and for comparatively accurate measurements at low stages.



The studies included under this line of research are directed toward the improvement of the integral systems made up of the components dealt with under (1) and (2) above. In the final analysis the field technician and the farmer are interested in the complete terrace outlet, gully control, water spreading, or other system, and the final aim of research in conservation hydraulics should be the development of safe, practical, and economical water-handling systems to meet the many different conditions existing on farm lands. The studies of complete systems will be carried out principally under actual field conditions on projects of the Soil Conservation Service.

(4) The fourth of the hydraulic studies consists of investigations of water-erosion processes as a basis for the control of storm run-off.

The studies under this project will be conducted both in the field and in the laboratory in an effort to delineate the fundamental relationships between the factors involved in the water-erosion process. Studies will be made of erosion by surface flow, the effect of slope characteristics, velocities and depths of flow, the development of erosion patterns on farm lands, and other fundamental factors involved in the water-erosion process.

(5) The fifth of the hydraulic studies consists of the development of devices and methods for determining the erosion and run-off from experimental areas, and studies of other equipment used in soil and water conservation research. (See fig. 43



for a view of Type-H flume developed in the Bureau of Standards Hydraulic Laboratory by engineers of this Section for measurement of flow of water with minimum amount of silting and for comparatively accurate measurements at low stages.)

These studies deal with the instruments and technique required in soil and water conservation research and are therefore fundamental. The principal studies under way are directed toward the improvement of methods of sampling and analyzing soil and water mixtures; the development of dividers and rate-measuring devices; the improvement of water stage and rainfall recorders; and the invention of artificial sprinkling and other apparatus needed in the comparatively new field of research now being entered by the Soil Conservation Service.

Some of the accomplishments to date of the Hydraulics Section follow:

Determinations of the run-off capacities of various designs for use in check dams and similar structures were made at the Outdoor Hydraulic Laboratory at Spartanburg, S. C. Capacities of specific erosion-control structures were determined at the Minneapolis Laboratory preliminary to their construction in the field. The tests dictated the need for a change in design in the case of a drop inlet highway culvert in order to prevent overtopping of the highway, and resulted in the adoption of a more economical design in the case of the head spillway structures.



Reports were prepared on the results of tests performed at the California Institute of Technology giving construction designs for scour prevention works for use below structures of the free overfall type. The Minneapolis Laboratory determined a satisfactory type of scour prevention structure at the foot of a steep chute to be used to stop the advance of a large gully.

Determinations of flow capacities and allowable velocities short of excessive scour in vegetated channels were continued at the Spartanburg Laboratory. The variables were type and stage of growth of vegetation and channel shape, slope, and curvature. Facilities for additional work along this line, under different climatic conditions, are under preparation at Stillwater, Okla., and McGredie, Mo.

The work initiated at the National Hydraulic Laboratory on the role of rainfall impact in the removal of soil from the land by run-off waters was continued at the Auburn, Ala. project. Three papers have been or are in the process of being published on this subject. It was found that large raindrops falling at high speeds on a small area of bare soil caused ten times more erosion than did small raindrops. In addition, the amount of water going into the soil was one-third as much for the large drops as for the small ones. From the standpoint of soil and water conservation these results indicate clearly the need for, and the primary function of mulches and vegetal covers.





The outstanding accomplishment of the year was probably in the field of channel hydraulics. The steady progress of the studies at the Spartanburg, S. C. Laboratory over the past few years on the capacities and permissible velocities in vegetated channels under a wide variety of conditions has resulted in the establishment of a mass of sound, acceptable data, usable in the design of safe channels for the disposal of run-off waters from the agricultural areas of the Southeast.

It is readily apparent that the hydrologic data being collected by the Soil Conservation Service will be useful not only to other agencies of the Department of Agriculture but also to many other Federal agencies, States, Municipalities, private companies, and individuals in planning works and structures that depend for their safety and economy upon a knowledge of rates and amounts of run-off for which provision must be made. For instance, the Public Roads Administration has use for such hydrologic data in the design of culverts, diversion ditches and check dams in roadside ditches. Municipal engineers have need for such data in planning water supplies for cities and in providing for run-off from outlying suburban areas tributary to storm sewers.

Preliminary results of the investigations being conducted by the Hydrologic Division have been published in numerous magazine articles. A number of mimeographed publications have been issued giving basic data collected at several of the soil and water conservation experiment stations of the Soil Conservation Service. Material has been prepared for publication of



printed bulletins covering the basic hydrologic data collected at the large experimental watershed projects at Coshocton, Ohio; Waco, Texas; and Hastings, Nebr. Following is a list of articles, reports and bulletins relating to work of the Hydrologic Division that have been published or prepared for publication during the fiscal year ending June 30, 1941:

PUBLICATIONS OF THE HYDROLOGIC LAND USE SECTION

Reports and Papers During the Fiscal Year:

1. Hydrologic Studies - Spur, Texas - 1928-38, mimeographed report
2. Hydrologic Studies - Bethany, Mo., - 1933-40       "
3. Hydrologic Studies - Hays, Kansas - 1930-38       "
4. Some Factors which Influence Infiltration and Its Measurement in Houston Black Clay - Journal Ameri. Soc. of Agronomy, Nov. issue, 1940
5. Studies on Soil Moisture Relationships at North Appalachian Experimental Watershed - Proc. of Soil Sc. Soc. of Ameri.
6. Silt Samplers Compared in Special Tests - Civil Engineering - Jan., 1941, Vol 11 #1, pp 3-6
7. A Comparison of the Colorado and Type-F Artificial Rainfall Applicators, Hastings, Nebr. - mimeographed report
8. Watershed and Hydrologic Studies in the Central Great Plains - Agric. Engineer., June, 1941, Vol. 22, #6, pp 215-217

Reports and Papers Prepared and Approved for Publication:

1. Soil Volume Changes and Accompanying Moisture & Pore Space Relationships, recommended for publication in Agric. Engineering or Soil Science or Journal of Ameri. Soc. of Agronomy
2. Hydrologic Data - North Appalachian Experimental watershed, Coshocton, Ohio - 1939, Hydrologic Bull. No. 1, to be published as a Dep't Bull., in galley proof
3. Hydrologic Data - Blacklands Experimental Watershed, Waco, Texas, 1937-39, Hydrologic Bull. No. 2, to be published as a Dep't Bull., in hands of printer
4. Hydrologic Data - Central Great Plains Experimental Watershed - 1938-40 - Hydrologic Bull.
5. Watershed Description - Blacklands Experimental watershed - Hydrologic Bull.





6. Surface Condition of Soil and Time of Application as Related to Intake of Water - Dep't Cir. 608
7. Hydrologic Studies - Tyler, Texas - 1931-39, mimeographed report
8. Soil and Water Losses from Three Areas Devoted to Different Land Uses, to be mimeographed as Release No. 1 for distribution to Region 5 of the Soil Conservation Service

#### PUBLICATIONS OF THE RUN-OFF STUDIES SECTION

##### Reports and Papers Published During the Fiscal Year:

1. Run-off from Small Agricultural Watersheds - Agricultural Engineering, Dec. 1940, Vol. 21, #12, pp 479-482
2. An Ice Storm in Texas - Soil Conservation, April, 1941, pp 241-242 and 248
3. Run-off and Watershed Yield - Engineering Handbook, Pacific Northwest Region, Soil Conservation Service

##### Reports and Papers Prepared and Approved for Publication:

1. Preliminary Report on Peak Rates of Run-off Secured from the Run-off Studies at Fennimore, Wisconsin, to be mimeographed
2. Run-off from Terraced Areas Under Conditions of Extreme Flood - Trans., Ameri. Geophys. Union
3. Preliminary Results of Run-off Studies at Fennimore, Wisc., Showing Low Rates and Amounts of Run-off - Trans. of Ameri. Geophys. Union
4. Intensity-Duration-Frequency of Precipitation in the Pacific Northwest - Proc. of Ameri. Soc. of Civ. Engin.

#### PUBLICATIONS OF THE HYDRAULICS SECTION

##### Reports and Papers Published During the Fiscal Year:

1. Hydraulic Tests of Kudzu as a Conservation Channel Lining - Agricultural Engineering, Jan. 1941, pp 27-29
2. Recent Studies in Raindrops and Erosion - Agricultural Engineering, Nov. 1940, Vol. 21, #11, pp 431-433
3. Tests of a Centipede Grass Channel Lining - mimeographed report.

##### Reports and Papers Prepared and Approved for Publication:

1. Measurements of the Fall-Velocity of Waterdrops and Raindrops - Trans. of Ameri. Geophys. Union
2. An Experimental Determination of the Energy Loss in a Hydraulic Structure of the Free Overfall Type - Proc. of Ameri. Soc. of Civ. Engin.
3. Hydraulic Model Tests of Conventional Drop Structures - Some West. Coast Periodical







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